

**Marine Physical
Laboratory**



of the Scripps Institution
of Oceanography
University of California,
San Diego

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Australian Humpback Whales and Ambient Noise

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14. ABSTRACT This report describes the research performed on behalf of the Office of Naval Research (grant # N00014-02-1-1013). The goal of the Humpback Acoustic Research Collaboration (HARC) is to understand the behavioral responses of large marine mammals (baleen whales) to their surrounding acoustic environment.					
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Scientific and Technical Objectives

The goal of the Humpback Acoustic Research Collaboration (HARC) is to understand the behavioural responses of large marine mammals (baleen whales) to their surrounding acoustic environment.

Scientific objectives of HARC include understanding how natural and anthropogenic sound levels affect whale migration and smaller scale movement patterns and the possibility of navigation via ambient acoustic cues. The deduction of what signals and source levels the Humpback whales are sensitive to and what sources are capable of masking these signals as well as seeing how baleen whales may modify their behaviour to enhance SNR for communication and cognisance. This information is critical to better mitigate anthropogenic effects on marine mammal populations.

Approach

The fundamental thesis of the HARC project is that the effects of the ambient ocean noise field (from natural and anthropogenic sources) on baleen whales (Humpback, *Megaptera novaeangliae*) can be deduced by making careful observations in the presence and absence of sound. Visual observations from land and surface vessels are co-ordinated with subsurface tracking of singing whales using hydrophone arrays. Detailed observations of individual whale behaviour are made using sophisticated digital tags attached by suction cup to selected individuals to compliment the observations of pods and populations. The detailed structure of the ambient noise field, physical oceanography and meteorology in the study site are characterised to define the physical acoustics of the environment. Observations are made during periods with and

without varying levels of anthropogenically produced and naturally occurring noise.

HARC involves an international group of participants from SIO, WHOI, Australia's DSTO and Univ. of Queensland. Experiments have taken place in the fall 2003 and will continue in the fall of 2004 at Peregrine beach, 150 km north of Brisbane in Queensland Australia. This region is visited by migrating, Humpback whales (>4500 individuals), most travelling within 10 km of the coast. This region has only sparse shipping traffic, usually less than 2-5 ships per day and consequently has low background levels of ambient noise.

Concise Accomplishments

The 2004 field season was extremely successful. Over 400 hours of visual and acoustic tracking was accomplished; data was recorded from approximately 1100 whales. In addition, 20 whales were successfully tagged using DTAG's for 69 hours including 9 focal follows on mother/calf pairs. This data has been synchronized with surface and acoustic tracking, behavioural recording, and tissue sampling for sexual identification.

Dart tissue sampling for a genetics study was successful and linked with individuals already identified using an historical fluke - photo database. A test of a non-invasive DNA fingerprinting technique and hormone analysis using blow sampling was successful and samples were collected during the Dtagging process.

A vertical acoustic array was deployed, allowing 3D positioning in addition to the 2D positioning available with the primary hydrophone array. Surface meteorology, wave spectra, water temperature, offshore current, and density structure and the surf generated ambient noise was recorded throughout the study interval.

The HARC project proved the utility of this study site in Australia to enable a highly co-ordinated experimental study of large marine mammals not normally accessible to researchers. It has proven possible to synchronize biological and physical oceanographic metrics in a manner providing the correct acoustic context for interpretation.

Expanded Accomplishments

The fall 2004 field season was a very successful second, and final, experimental deployment. All the separate research parties managed to deploy their instrumentation and collect data. In addition to the originally planned tasks, additional researchers from Australia and the USA were able to use the HARC logistical support to expand the overall research aims of the project by adding to the data being collected (including match field processing of singers with a vertical acoustic array (Aaron Thode, MPL).

Figure 1 illustrates a timeline of experimental deployment during the 2004 period, the instrumentation deployed, and the number of observed whales during that time period. Observations were conducted for more than 400 hours tracking 803 pods, including more than 100 singers out of approximately 1200 individuals. An estimate of the total number of whales migrating through the HARC study site is >3000 individuals during the study period which agrees with estimates of >4500 whales in this growing population. Acoustic tracking was very successful using ISHMAEL software in conjunction with the visual theodolite tracking program Cyclops (from the University of Newcastle). Cyclops software is able to input subsurface tracking data from ISHMAEL and this combined information is displayed to the researchers to provide quick and accurate determinations of whale position (to within approximately 1 m). All tracking data is transferred between the station base at Peregrine Beach, Mt. Emu (visual tracking site) and offshore boats using the wireless

"PerigiNet" computer network installed for the experimental period. The utility of the Cyclops software was further proven in that HARC cooperating researchers are now incorporating Cyclops in their own projects in the USA and abroad.

Meteorological information was collected from the base station (wind speed, direction, temperature, sea state) and wave spectra, water temperature and currents from an offshore instrument. The leaking buoys and problems with the solar panel recharging system for the hydrophone arrays were all corrected allowing almost maintenance-free operation during the season. Ambient noise recordings of surf levels (and anthropogenic sounds) were recorded using an autonomous bottom-mounted system that was recovered at the end of the season. CTD casts along the study area were conducted whenever possible to facilitate the calculation of an accurate sound speed profile. Gaps in the time record of the acoustic array indicate when offshore buoys (there were 5) were offline during battery changes. However, at all times, at least 3 buoys were active, enabling accurate acoustic tracking of the passing whales.

Dart tissue sampling by crossbow was successful and has provided genetic data for a population study by the University of Queensland and tissues samples have been collected from whales that can be identified from the fluke-photo historical database for eastern Australia. Additional fluke and dorsal photographs taken during HARC are added to this photographic record. An exciting new, non-invasive technique for sample collection was again successfully employed by researchers from the Sydney Zoo. Whale blow samples were collected from the air and analyzed for hormone and DNA content. "Wiping" the air using a special sampling net attached to the end of the bow-mounted tagging pole (used for Dtags) proved to be an easy way to collect these samples with minimal disturbance to the whales.

Figures 2 and 3 show the results visual/acoustic observation and D-tagging. Figure 2 shows complex interactions occurring between a mother/calf pod, singers and escorts in a single 3-4 hour session as

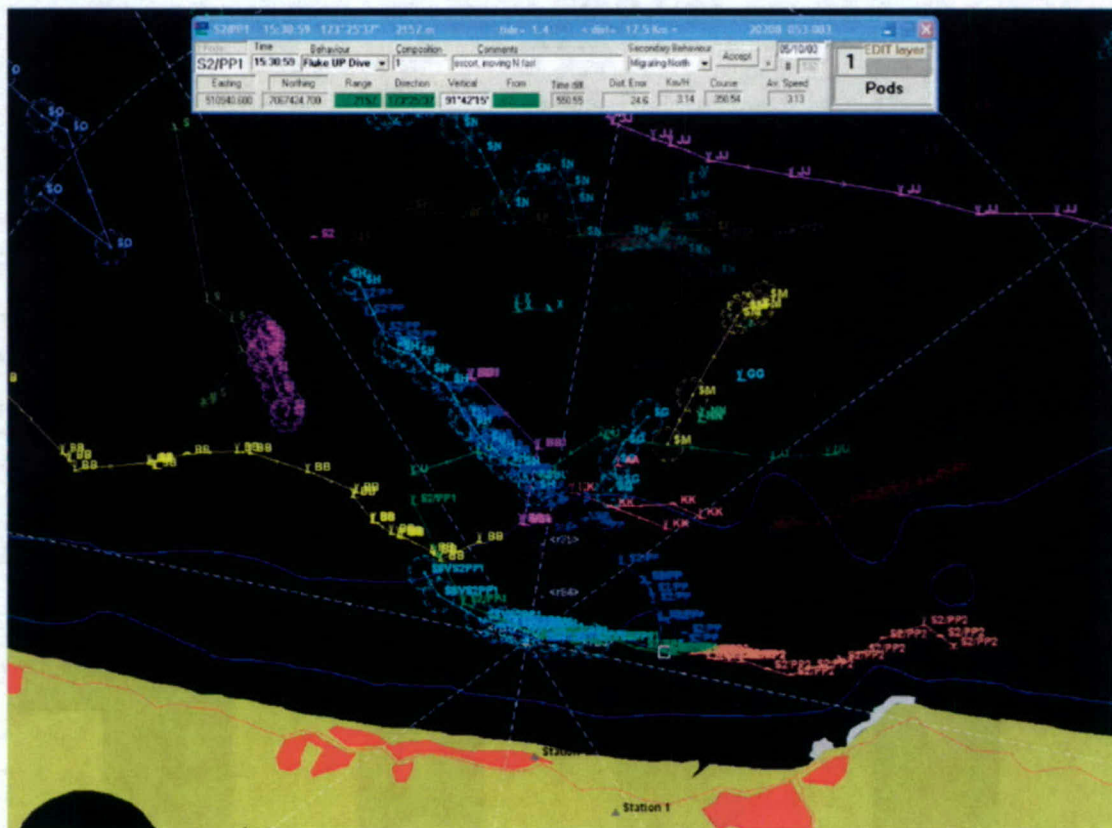
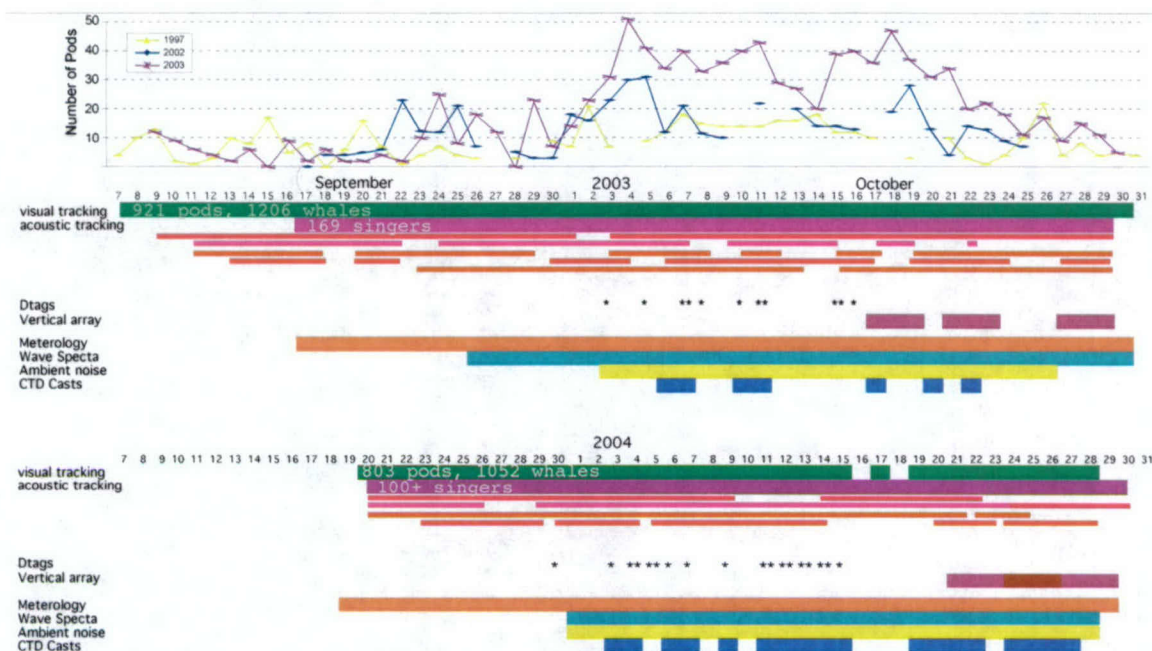
recorded by the coordinated Cyclops and Ishmael tracking teams. Hundreds of behavioural events were followed during the HARC deployments.

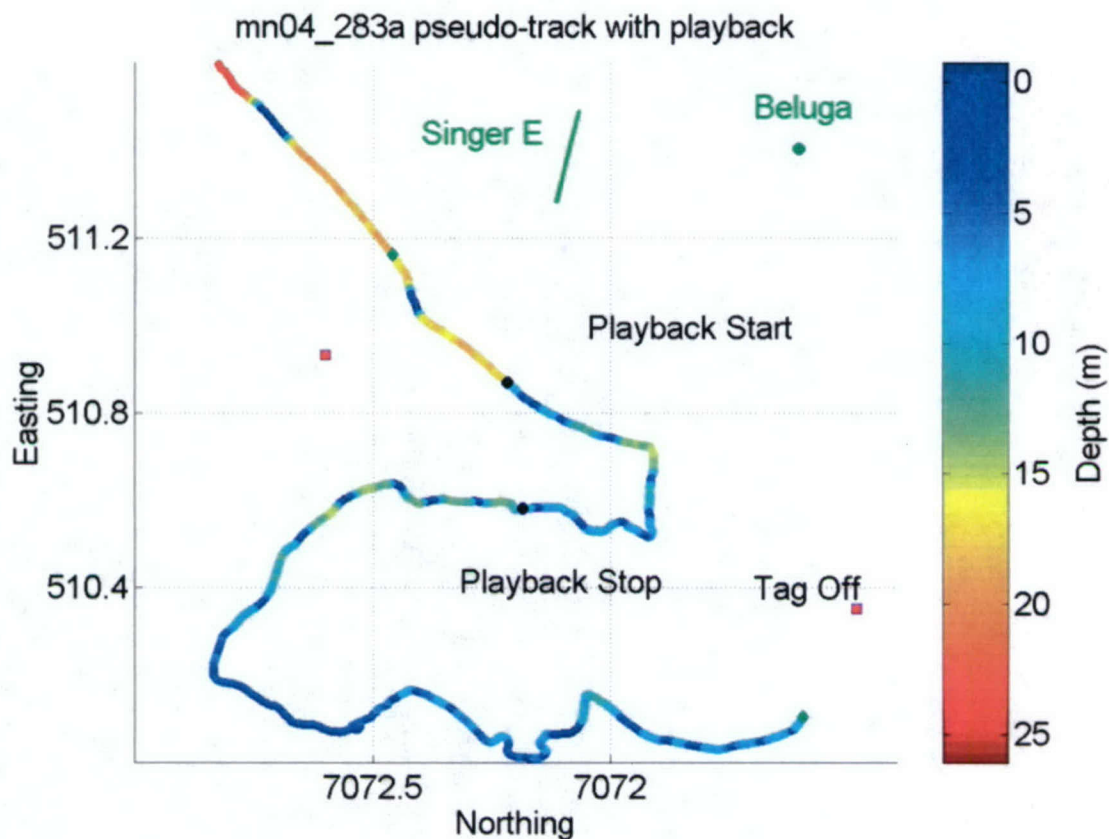
20 whales were successfully tagged in 2004, recording over 68 hours of data. This is totals 30 more Humpback whales than had ever been previously tagged before HARC. Following tagged whales for tag retrieval was very successful using the combination of acoustic and visual tracking and information sharing using PerigiNet. No tags were lost during this deployment season and tagging operations were possible on 11 out of 15 days operating. There was a high degree of social behaviour being recorded, both visually and with the tags (not just simple migratory swimming) -- an emphasis on discerning these behaviours (competitive interactions, escorting etc>) will be a matter of detailed analysis of the collected data sets.

The HARC study site proved to be a convenient area for controlled exposure experiments (playbacks) and a dozen playbacks (of tones and social sounds) were accomplished and successful. Even the low energies available using the J11 projector elicited responses (see figure 3).

HARC has been highly successful. All research groups are interacted together very well and synchronization of data has proceeded smoothly. The project was so successful that other marine mammal researchers have been eager to participate in future deployments, and/or have expressed interest in access to HARC data sets. The additional sharing of data is being considered on a case by case basis.

Uploaded Files:





Work Plan

The field work for the HARC project was completed in Nov 2004 and the program will have finished its funding in spring 2005. Over the next 12 months (and into the future) data collected during the 2003 and 2004 field seasons will be analysed.

Problems/Issues

There were no problems identified during the 2004 field season. Previous issues with the J11 sound projector were mitigated and playback experimentation was successful and proved the utility of this type of manipulative work in the shallow water off Australia.

All the researchers involved in the HARC project bemoaned the lack of funds available for proper data analysis post project.

Peer-Reviewed Journal Articles

Status Text

In Press Thode, A.M., Gerstoft, P., Burgess, W.C., Guerra, M., Stokes, M.D., Noad, M.J. and Cato, D.H. "A portable matched-field processing system using passive acoustic time synchronization." :IEEE Journal of Oceanic Engineering

Published Thode, A.M., Gerstoft, P., Guerra, M., Noad, M.J., Stokes, M.D. and Cato, D.H. (2004). "Matched-Field Processing of Humpback Whale Song Off Eastern Australia." Proc. Acoustics 2004, Australian Acoustical Society, Gold Coast, 3-5 November 2004:, pp 259 – 362.

Published Noad, M.J., Cato, D.H. and Stokes, M.D. (2004). "Acoustic Tracking of Humpback Whales: Measuring Interactions with the Acoustic Environment." Proc. Acoustics 2004, Australian Acoustical Society, Gold Coast, 3-5 November 2004: pp 353 – 358.

Published Cato, D.H., McCauley, R.D. & Noad, M.J. Potential effects of noise from human activities on marine animals. Proceedings of Acoustics 2004, Australian Acoustical Society, Gold Coast, 3-5 November.: 369-74.

Books or Book Chapters

No book or book chapters reported.

Technical Reports (Non-refereed Publications)

No technical reports reported.

Abstracts/Presentations/Posters/Conference Proceedings

Cato, D.H., Noad, M.J., Stokes, D., Kniest, E., Biassoni, N., Miller, P. and Deane, G.B. (2005) "Acoustic and tracking techniques in the humpback whale acoustic collaboration (HARC)." Proc. International Conference on Underwater Acoustic

Measurements: Technologies & Results, Heraklion, Crete, Greece, 28 June – 1 July 2005.

Cato, D.H., Noad, M.J. and Stokes, M.D. (2003) "Pilot studies for the Humpback Whale Acoustic Research Collaboration (HARC)" Symposium on the Environmental Consequences of Underwater Sound, San Antonio, Texas, 12-16 May, 2003.

Stokes, M.D., Noad, M.J., Deane, G., Cato, D.H. and Johnson, M. (2003) "HARC: the humpback whale acoustic research collaboration" Symposium on the Environmental Consequences of Underwater Sound, San Antonio, Texas, 12-16 May, 2003.

Stokes, M.D., Noad, M.J., Deane, G., Cato, D.H. and Johnson, M. (2005) "HARC: the humpback whale acoustic research collaboration" Symposium on the Environmental Consequences of Underwater Sound, Washington DC, 2005.

"Matched-field processing of Humpback Whale Song off Eastern Australia," (extended abstract) Aaron Thode, Peter Gerstoft,

Melania Guerra, Michael Noad, Dale Stokes, Douglas C. Cato, presented at Acoustic Inversion Methods and Experimental Assessment of the Shallow Water Environment, June 29, 2004

"Matched-field processing of Humpback Whale Song off Eastern Australia," (extended abstract), Aaron Thode, Peter Gerstoft, Melania Guerra, Michael Noad, Dale Stokes, Douglas C. Cato, ACOUSTICS 2004, Gold Coast, Queensland, Australia, Nov. 4, 2004

"Range-depth tracking of humpback whales using autonomous acoustic

recorders" (abstract) Aaron M. Thode, Peter Gerstoft, Melania Guerra, Dale M. Stokes, William C. Burgess, Michael J. Noad, Douglas H. Cato, J. Acous. Soc. Am. 116(4), 2589, Dec. 2004

"Modular autonomous array deployments using passive acoustic time

synchronization," (Invited abstract, Bioacoustics), Aaron Thode and William C. Burgess, J. Acous. Soc. Am. 117(4), 2525, April 2005.

"Matched-field tracking of humpback whales using ambient noise time

synchronization", (Invited abstract, Acoustical Oceanography), Aaron

Thode, Peter Gerstoft, Dale M. Stokes, William C. Burgess, Michael J. Noad, Douglas H. Cato, scheduled for Oct. 2005 Acoustical Society of America conference in Minneapolis, Minnesota.

Awards/Honors/Invention Disclosure

No awards/honors reported.

Patents Submitted

No patents submitted reported.

Patents Issued

No patents issued reported.

Technology Transfer

The HARC project was a very visible scientific endeavour in Australia. This collaboration between US and Australian Naval researchers received a lot of media attention and was specifically mentioned in Australian parliament as an example of scientific co-operation between countries. The HARC research was featured on the BBC and Australian Radio programs, numerous newspaper and magazine articles as well as on several local and national television news programs, and featured in several "science news magazine" and nature documentary television programs from 2003-2005.

This high degree of community outreach was continued through the 2004-2005 field season and it served as an excellent means of educating the public on marine mammal research, naval research policy and the co-operative role of science world-wide.

ONR Database Statistics

Use of Human Subjects No

DoD Personnel Used

Use of Animals Yes

Animals Used Marine Mammals

Use of Recombinant DNA No

Degree(s) Granted 0

PI/CoPI Information

0	PI/CoPI Minority Women**		
2	PI/CoPI Non-Minority Women		
0	PI/CoPI Minority Men**		
6	PI/CoPI Non-Minority Men		
	Minority	Non-Minority	Total
Women	0	2	2
Men	0	6	
Total	0	8	8

Post Doctoral Information

1	Post Doctoral Minority Women**		
2	Post Doctoral Non-Minority Women		
0	Post Doctoral Minority Men**		
1	Post Doctoral Non-Minority Men		
	Minority	Non-Minority	Total
Women	1	2	3
Men	0	1	
Total	1	3	4

Grad Students Information

1	Grad Students Minority Women**
13	Grad students Non-Minority Women

2	Grad Students Minority Men**		
1	Grad Students Non-Minority Men		
	Minority	Non-Minority	Total
Women	1	13	14
Men	2	1	3
Total	3	14	17

Publication Totals

Total Number of Peer-Reviewed Journal Articles: 4

Total Number of Books or Chapters: 0

Total Number of Technical Reports: 0

Total Number of Patents Issued: 0

Total Number of Patents Pending: 0

*** Under-represented or minority groups include Blacks, Hispanics, and Native Americans. Asians are not considered an under-represented or minority group in science and engineering.*

****Supported at least 25% this year on contract/grant.*

Other Sponsored Work

No sponsored work reported.

Foreign Collaborations

INVESTIGATOR	ORGANIZATION	LOCATION	TOPIC OF COLLABORATION
Dr Doug Cato	Defense Science and Technology Organization		
	Sydney, Australia	Co-PI in HARC project,	liason with Australian Defense
Dr. Mike Noad	University of Queensland	Brisbane, Australia	
		Co-PI in HARC project	
Dr. Patrick Miller	St. Andrews University	St Andrews, Scotland	
		Co-PI in HARC project.	transferred to St. Andrews from WHOI during project